Top and root MOISTURE CONTENT

of stored Douglas-fir planting stock

BY ROBERT F. TARRANT

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE

U.S. FOREST SERVICE
RESEARCH PAPER PNW-13
1964

U. S. FOREST SERVICE
RESEARCH PAPER PNW-13

Top and root MOISTURE CONTENT

of stored Douglas-fir planting stock

BY ROBERT F. TARRANT

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
Philip A. Briegleb, Director
Portland, Oregon

U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
JUNE 1964

CONTENTS

	Page
INTRODUCTION	1
STUDY METHODS	1
RESULTS	2
Top and Root Moisture Content of Seedlings Stored 0 to 8 Weeks	2
Factors Affecting Ratio of Top/Root Moisture in Seedlings Stored 0 to 24 Weeks	3
DISCUSSION	4
SUMMARY	7
LITERATURE CITED	8

INTRODUCTION

In the Pacific Northwest, Douglas-fir *(Pseudotsuga menziesii)* is usually planted in late fall or early spring when high soil moisture and cool, rainy weather prevent plant desiccation. Under optimum conditions, healthy-appearing seedlings, often dripping with water, are carefully placed into soil which is at or near field moisture capacity and are almost continually wetted with rain for several months. Yet, with cessation of rainfall and onset of warm weather in late spring or early summer, many such seedlings may show signs of distress and soon die.

Because the first warm, dry days in late spring or early summer frequently coincide with seedling mortality, death of seedlings is often subjectively attributed to excessive heat or drought. However, some findings point to the possibility that preplanting desiccation, a condition most difficult to detect visually, may sometimes be responsible for early season mortality.

Original purpose of this study was to find whether seedlings maintained their initial moisture content during 24 weeks' storage at 35° F. and 95-percent relative humidity. After only 8 weeks, however, normal cold storage conditions were interrupted, because changes in storage schedules and shifts of stored stock necessitated frequent opening of the cooler and some intermittent operation of the refrigeration system. Because analysis of seedlings sampled to that time indicated that the relationship between top and root moisture appeared to vary with changes in total seedling moisture content, the remaining seedlings stored for study were left in the coldroom where they slowly lost moisture in the absence of normal storage conditions.

STUDY METHODS

Seedlings were collected at Wind River Nursery[1] in late October during routine packing of stock of a Willamette National Forest seed source. Thirty-five lots of 10 seedlings each were removed at random from a total of about 2,000 passing over the conveyor belt and were randomly combined into 7 groups of 50 trees each. One group was taken for immediate analysis, and the remaining six were marked and placed at random within one shipping bundle of 2,000 seedlings. The roots were packed in moist cedar shavings (shingle tow) and the tops were exposed outside the bundle wrapping. After being tied, the bundle was stored in a cooler.

At 4-week intervals, a group of 50 trees was removed from the bundle. Each seedling was severed at ground line, and resulting top and root portions were placed in separate sealed containers. Container and contents were weighed to the nearest 0.01 gram, after which the top or root portion was removed from the container, washed over filter paper to collect soil particles, then dried to a constant weight at 95° C. Weight of adhering soil and its moisture was subtracted from gross fresh weight to enable calculation of ovendry weight of clean tops and roots. Moisture content, as percent of dry weight, was calculated for each top (M_t), root (M_r), and entire seedling (MC).

[1]Operated by the U.S. Forest Service at Carson, Wash.

RESULTS

Top and Root Moisture Content of Seedlings Stored 0 to 8 Weeks

The relation of M_t and M_r to length of time seedlings were in normal storage was studied in a regression analysis which included data for only the first 8 weeks. When seedlings were packed, M_t and M_r were essentially the same (table 1). After both 4 and 8 weeks' storage, M_t and M_r had increased significantly over the previous observation, but M_r had increased at a faster rate (fig. 1). It is thus evident that seedling moisture content was not impaired by about 2 months' cold storage.

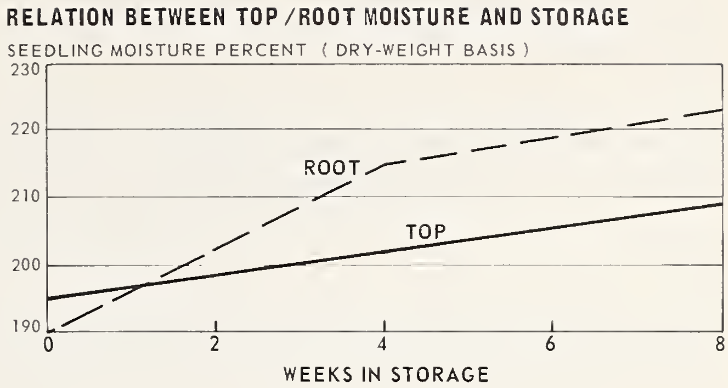
Table 1. – Average moisture content and coefficient of variation of seedling parts for each periodic sampling

Weeks stored[1]	Moisture content of plant part			Coefficient of variation[2]		
	Whole	Top	Root	Whole	Top	Root
	Percent					
0	191	195	190	12	15	17
4	207	202	215	11	17	16
8	215	209	223	13	16	17
12	136	154	115	16	18	20
16	147	171	121	9	11	15
20	58	75	39	20	25	40
24	94	115	78	21	30	36

[1] Between 0 and 8 weeks, seedlings were stored at 35° F. and 95- percent relative humidity. After 8 weeks, this environment was only intermittently maintained, which allowed slow drying of seedlings.

[2] Standard deviation expressed as percent of the mean dry weight.

Figure 1.—Relation between top and root moisture and number of weeks in storage at 35° F. and 95-percent relative humidity.



Hellmers *(5)* reported that moisture content of stored stock was higher than that of freshly dug stock for both 1-1 Jeffrey pine *(Pinus jeffreyi)* and 2-0 ponderosa pine *(Pinus ponderosa)*. He concluded that the difference might be due to drying conditions in field in contrast to storage environment, which includes moist packing material about roots and protection of tops from desiccating air movement. Possible sources of water gained by seedlings in storage, aside from that in the packing material, include moisture in the atmosphere and in soil particles adhering to roots.

An increase in water content soon after seedlings are placed in cool, humid storage might be explained simply as an adjustment of water losses during lifting and packing. However, such an adjustment should normally take place in a short time. If observed rise in moisture percent over a period of 8 weeks is real, then some other factor, perhaps metabolic plant activity, might have influenced moisture measurements. Possible effects include a decrease in plant dry weight through respiration of reserve foods or a gradual increase in hygroscopic compounds resulting from transformations within the plant of starch, reserve protein, and fats.

The continued rise of seedling moisture percent over 8 weeks might also be explained on the basis of respiration effects. When roots are tightly wrapped, as in a storage bundle, high CO_2 concentrations often develop. In some plants, an increase in CO_2 concentration of their environment slows absorption of water *(8)*. Thus, if CO_2 had accumulated substantially in the bundle of seedlings studied, the water deficit existing at time of packing might have been only slowly overcome during the 8-week storage period.

Factors Affecting Ratio of Top/Root Moisture in Seedlings Stored 0 to 24 Weeks

Data for all 350 seedlings sampled periodically for 24 weeks were analyzed by multiple regression *(4)*. The dependent variable for this analysis was the ratio (R) of top root moisture percent, where $R = \frac{M_t}{M_r}$.

Independent variables were:

1. Total seedling moisture percent (MC)
2. Total seedling weight (W)
3. Weeks in storage (P)
4. MC x P
5. MC^2
6. W^2

RELATION OF TOP/ROOT MOISTURE TO SEEDLING MOISTURE

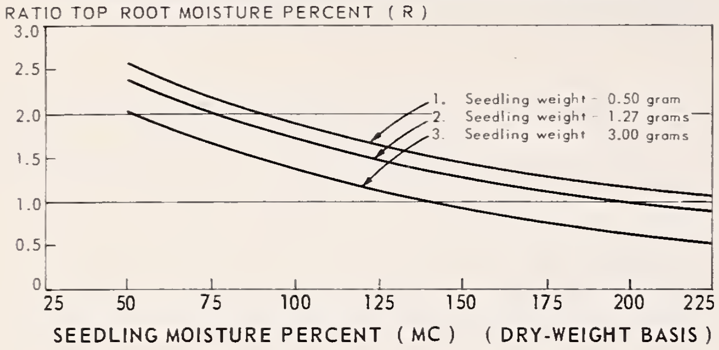


Figure 2.—Relationship of top/root moisture percent (R) to seedling moisture percent (MC).

Independent variables 3, 4, and 6 failed to account for a significant proportion of the total variation in R. The equation of best fit, which led to the curves in figure 2, was taken as:

$$R = 3.509 - 0.0185MC - 0.2017W + 0.0000365MC^2$$

The mathematical model underlying the regression analysis is based on the assumption that each seedling represents an independent observation. Actually, seedlings were stored within the bundle in groups of 50, so this assumption of independence is not completely tenable.

When seedlings were bundled at a MC of 191 percent, top moisture percent was 195, that of roots was 190, and R was 1.03, indicating that water was nearly balanced within the plant. When plants lost water, however, R increased – tops contained relatively more water than roots. At a MC of 80 percent, top moisture was 107 percent but root moisture was only 53 percent (R = 2.00) and seedlings had lost nearly 70 percent of their original water.

Seedling size (dry weight) appeared to affect the value of R. Compared with the average seedling of 1.27 grams, smaller seedlings had a higher R – the disparity between top and root moisture was greater at any given MC. On the other hand, larger seedlings displayed a lower R, indicating that they might better resist changes in internal water balance as they dried. This finding, however, is only tentative. The observed effect of seedling size on R may be real, but again it may only reflect differences in plant succulence due to size.

DISCUSSION

Varying need for water among various plant tissues is probably one explanation for the widening difference between top and root moisture during seedling drying. Stored seedlings, presumably like those growing in soil, transpire moisture whenever there is a vapor-pressure gradient from leaves to air. As long as roots remain in contact with an adequate source of moisture, foliage transpiration losses are replaced by water absorbed by roots from their surroundings. When the water source becomes curtailed, as in drier packing material or soil, transpiration continues, although at a reduced rate. Plant tissues which can produce the highest diffusion-pressure deficit then obtain water from those having lower deficits *(7)*.

Results of the current study show that as Douglas-fir seedlings dry, root moisture becomes substantially lower than top moisture. This consistent relationship indicated that subjective

evaluation or even actual determination of seedling top moisture may not be a good measure of the extent of whole plant desiccation.

Apparently, foliage samples can be safely used to determine total moisture content of only those seedlings freshly dug from moist soil. However, if plants have been subjected to drying after lifting, then sampling only top or needle moisture might lead to an erroneous estimate of total seedling moisture and its distribution within the plant.

Another precaution indicated by this study pertains to the method used for sampling seedlings. Despite random selection of trees from the conveyor belt after culling, seedling size varied widely, both within and between 50-tree sample groups (table 2). Thus, in future research on moisture content of nursery seedlings, samples should be drawn on a predetermined basis, such as weight or stem diameter, to achieve greater uniformity of seedling size.

Table 2. – Average ovendry weight and coefficient of variation of seedling parts for each periodic sampling

Weeks stored	Weight of plant part			Coefficient of variation[1]		
	Whole	Top	Root	Whole	Top	Root
	- - - - - - - - - - Grams - - - - - - - - -			- - - - - - - - - - Percent - - - - - - - - -		
0	1.35	0.75	0.60	44	49	45
4	1.19	.65	.54	47	52	45
8	.99	.53	.46	55	55	60
12	1.52	.83	.69	56	58	52
16	1.15	.61	.54	37	43	35
20	1.21	.66	.55	58	58	61
24	1.41	.73	.68	54	66	49

[1] Standard deviation expressed as percent of the mean.

If the observed relation of top/root moisture percent and seedling size is valid, it indicates that in further research on tree seedling moisture relationships we must take into account size of plants with which we are working. First need is for detailed physiological studies to determine whether the relationship between tree size and moisture balance was indeed real or was peculiar only to the planting stock used in the experiment. Additional research of the type proposed might well be associated with studies such as that of Stone and Schubert *(10)* in which physiological condition of the seedling and various parts of the root system were considered.

Many occasions for seedling desiccation occur during lifting, grading, packing, storage, transit to planting site, and planting. Further, in dry, windy weather, newly planted seedlings may lose moisture more rapidly than their root systems can replace it. Seriousness of moisture loss in planting stock, including Douglas-fir, was brought out by Aldhous *(1):*

> Analysis of the causes of death of plants following planting showed that bad planting, severe drought following planting and damage during transit from nursery to planting area, each have contributed to losses following planting. In most cases, the primary cause of death was desiccation . . . .

Previous research helps interpret possible effects of increasing top/root moisture imbalance when Douglas-fir seedlings lose water. Although the work cited in the following paragraphs deals with plants growing in soil in contrast to nursery stock stored in bundles, moisture adjustment within the plant probably proceeds similarly in both cases.

The needle moisture content that represents a "lethal level" or threshold of plant death from desiccation was studied by Parker *(9)*. In several conifers including Douglas-fir, needles remained viable, by the tetrazolium test, until 50 percent or more of their original weight, dry tissue basis, had been lost. A Douglas-fir needle moisture content of 68 percent was associated with 100-percent viability, but one of 39 percent indicated total loss of needle viability.

Needle viability, however, is not necessarily a measure of whole plant condition. According to Brix *(2)*, a leaf moisture content of 110 percent was critical for loblolly pine *(Pinus taeda)* seedlings, because plants dried below this level did not recover after watering. He concluded that significant changes in the roots restricted water transport to the leaves in desiccated plants (needle moisture less than 110 percent), because leaves with water content as low as 76 percent regained turgidity when either detached leaves or plants with roots excised were placed with the cut end in water. Brix felt that the most likely explanation for the critical increase in root resistance to water uptake and transport was that increasing dehydration may have affected permeability of living root tissues and caused breaks in the water columns.

A critical leaf moisture content of 110 percent was also cited by Faulkner and Aldhous *(3)*. Survival of stored tree seedlings of 13 species, including Douglas-fir, was more than 70 percent when moisture content (presumably of needles) was 110 percent or more, but less than 5 percent at a moisture level of 40 percent or less. Between these limits, the relationship of survival to moisture content was linear.

Findings by Kramer *(6)* are pertinent to interpretation of current study results. He reported that even after roots of loblolly pine seedlings were killed with hot water, the tops would remain "alive" and unwilted for 2 weeks or more because considerable quantities of water were absorbed from the soil through dead root systems. He believed that water would continue to be absorbed

until the dead root systems were destroyed by decay. Kramer also felt that minerals would probably be absorbed through dead roots in amounts approximately proportional to quantity of water absorbed.

Thus, we have evidence that tops of desiccated seedlings contain substantially more water than roots do; that deleterious effects of desiccation probably occur first in roots; and that living roots are not necessary for maintenance of "live" plant foliage over a substantial period of time. We might, therefore, speculate as to the true cause of some seedling deaths in the late spring or early summer after planting.

A Douglas-fir seedling may be in apparently good condition for planting, judged subjectively from needle turgidity, color, and general appearance. This might be true especially during rainy weather or when plant surfaces are otherwise well wetted. However, if significant amounts of water were lost from the plant at some time between nursery lifting and field planting, roots might be injured or even killed. However, dead roots might continue to supply tops adequately with water during cool, rainy weather, masking for awhile any destruction of active root functioning.

Seedlings might thus continue to appear alive for some time after planting, even though the roots were mortally damaged. But at the onset of summer heat and soil moisture stress, foliage would also die and turn brown. Coincidence of recognizable seedling death with seasonally increased air temperature and decreased soil moisture, in this case, could lead the casual observer to erroneously assume heat and drought to be the causes of mortality.

SUMMARY

Top and root moisture percent, dry-weight basis, was studied in cold-stored, 2-year-old Douglas-fir seedlings.

During an initial 8-week storage period at 35° F. and 95-percent relative humidity, plants gained moisture. Roots apparently gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost moisture more rapidly than tops. The difference between top and root moisture percent at a given whole seedling moisture percent was greater for smaller seedlings and less for those of larger size.

A hypothesis, also supported by evidence from other research, is suggested that the difference in drying rates of tops and roots explains some otherwise puzzling spring or early summer mortality of seedlings planted under optimum conditions of soil moisture and weather.

LITERATURE CITED

1. Aldhous, J. R.
   1959. Polythene bags for movements of forest nursery stock. Empire Forestry Rev. 38: 65-76, illus.

2. Brix, Holger.
   1960. Determination of viability of loblolly pine seedlings after wilting. Bot. Gaz. 121: 220-223.

3. Faulkner, R., and Aldhous, J. R.
   1957. Nursery investigations. *In* Report on Forestry Research for the year ended March 1957. Brit. Forestry Comn., pp. 19-36, illus.

4. Grosenbaugh, L. R.
   1958. The elusive formula of best fit: a comprehensive new machine program. U.S. Forest Serv. South. Forest Expt. Sta. Occas. Paper 158, 9 pp., illus.

5. Hellmers, Henry.
   1962. Physiological changes in stored pine seedlings. U.S. Forest Serv. Tree Planters' Notes 53: 9-10, illus.

6. Kramer, P. J.
   1933. The intake of water through dead root systems and its relation to the problem of absorption by transpiring plants. Amer. Jour. Bot. 20: 481-492.

7. Kramer, Paul J., and Kozlowski, Theodore T.
   1960. Physiology of trees. 642 pp., illus. New York: McGraw-Hill Book Co., Inc.

8. Meyer, Bernard S., and Anderson, Donald B.
   1952. Plant physiology. Ed. 2, 784 pp., illus. New York: D. Van Nostrand Co., Inc.

9. Parker, Johnson.
   1951. Moisture retention in leaves of conifers of the northern Rocky Mountains. Bot. Gaz. 113: 210-216.

10. Stone, Edward C., and Schubert, Gilbert H.
    1959. The physiological condition of ponderosa pine (Pinus ponderosa Laws.) planting stock as it affects survival after cold storage. Jour. Forestry 57: 837-841, illus.

Tarrant, Robert F.
1964. Top and root moisture content of stored Douglas-fir planting stock. U.S. Forest Serv. Res. Paper PNW-13, 8 pp., illus.

Douglas-fir planting stock gained moisture over a period of 8 weeks in cold storage. Roots gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost increasingly more moisture than tops. Difference between top and root moisture was inversely related to seedling dry weight.

Differential drying of tops and roots may explain some puzzling early-season mortality of planted seedlings.

Tarrant, Robert F.
1964. Top and root moisture content of stored Douglas-fir planting stock. U.S. Forest Serv. Res. Paper PNW-13, 8 pp., illus.

Douglas-fir planting stock gained moisture over a period of 8 weeks in cold storage. Roots gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost increasingly more moisture than tops. Difference between top and root moisture was inversely related to seedling dry weight.

Differential drying of tops and roots may explain some puzzling early-season mortality of planted seedlings.

Tarrant, Robert F.
1964. Top and root moisture content of stored Douglas-fir Planting stock. U.S. Forest Serv. Res. Paper PNW-13, 8 pp., illus.

Douglas-fir planting stock gained moisture over a period of 8 weeks in cold storage. Roots gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost increasingly more moisture than tops. Difference between top and root moisture was inversely related to seedling dry weight.

Differential drying of tops and roots may explain some puzzling early season mortality of planted seedlings.

Tarrant, Robert F.
1964. Top and root moisture content of stored Douglas-fir planting stock. U.S. Forest Serv. Res. Paper PNW-13, 8 pp., illus.

Douglas-fir planting stock gained moisture over a period of 8 weeks in cold storage. Roots gained at a faster rate than tops.

When seedlings were subsequently dried slowly, roots lost increasingly more moisture than tops. Difference between top and root moisture was inversely related to seedling dry weight.

Differential drying of tops and roots may explain some puzzling early-season mortality of planted seedlings.